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Open-Cycle Hatcheries, Tourism and Conservation of Sea Turtles: Economic and Ecological Analysis

Abstract

Considers the role that tourism-based sea turtle-hatcheries can play in conserving populations of sea turtles by combining economic analysis of markets with ecological parameters. Background is provided on the nature and development of such hatcheries in developing countries, giving particular attention to Sri Lanka. The modelling provided helps with the assessment of the impacts of turtle hatcheries on the conservation of sea turtles and enables ecological consequences of tourism, based on such hatcheries, to be better appreciated than in the absence of such modelling. The results demonstrate that sea turtle hatcheries that operate for tourist purposes can make a positive contribution to sea turtle conservation, but this depends on the manner in which they are conducted. Possible negative effects are also identified.

Key words: ecological economics, nature conservation, sea turtles, ranching, developing countries, Sri Lanka, sea turtle hatcheries, tourism

Open-Cycle Hatcheries, Tourism and Conservation of Sea Turtles: Economic and Ecological Analysis

Introduction

All species of sea turtles, except the Australian flatback, are classified as either endangered or vulnerable (IUCN 1995) and all species are included in Appendix 1 of CITES (IUCN 1995). Sea turtles face many threats, both on land and at sea (cf. Marcovaldi and Thome 1999; NRC, 1990). A major threat to the survival of sea turtles in developing countries is the collection of eggs for human consumption (cf. Shanker and Pilcher 2003; Pilcher and Ismail 1999; Pilcher 1999; Richardson, 1994). Furthermore, in some developing countries where eggs are used for human consumption, a lot of eggs are also collected for sea turtle hatcheries that cater for tourists. This, for example, occurs in Sri Lanka (cf. Amarasooriya 2001), although it is also common in some other developing countries (cf. Chantrapornsyl 2002). Some turtle hatcheries, try to justify their existence on the basis that they help conserve the population of sea turtles by saving eggs from being consumed by humans (cf. Gampell 1999). Sea turtle hatcheries have, and are used as, an *ex situ* conservation tool in many countries (cf. Shanker 2003; Chan, 2001; UPM et al. 1996; Shanker 1994; NRC 1990). Nevertheless, doubts have been raised about the success of such operations (cf. Hewavisenthi 1993), even though it is widely accepted that well-managed sea turtle hatcheries can play a positive role in turtle conservation when *in situ* conservation is not possible or is impractical (cf. Chan 2001; IUCN/SSC Marine Turtle Specialist Group, 1999; IUCN 1995).

A strong correlation seems to be present between the numbers of sea turtle hatcheries or quantity of eggs collected for hatcheries and tourism in some developing countries. For example, in Sri Lanka where there is a high density of tourists in the southwest of the country, the number of hatcheries is also high. This may partly explain why some sea turtle hatcheries are not mainly motivated by conservation aims, but rather exist for commercial gains from tourists. In fact, some of these hatcheries operate only during the tourist season (cf. Hewavisenthi 1993)[1].

A substantial quantity of sea turtle eggs are collected for human consumption in some developing countries, for example, in Sri Lanka, Indonesia, Malaysia and India (cf. Amarasooriya 2001; Pilcher 1999). With the development of turtle hatcheries, the price of collected turtle eggs often increases due to competition between hatcheries and those who want to consume them.

Sri Lanka is one of the few countries where five species of sea turtles nest throughout the year in significant numbers (cf. Amarasooriya 1999) although the numbers nesting decreases in some months in certain areas. In such months, human competition for eggs becomes intense. When eggs are scarce, collectors travel long distances in search of eggs and sometimes into remote and protected areas such a national parks. In such cases, eggs have to be transported long distances. Furthermore, where *in situ* conservation is practiced, guards have to be employed to protect eggs from being poached.

Sea turtle hatcheries, it has been shown, can make a positive contribution to sea turtle conservation if they are managed using appropriate scientific guidelines (Chan 2001). This is especially so when *in situ* conservation is expensive and impractical. If hatcheries are not well managed, survival rates of hatchery-released turtles may in fact be lower than in the wild. Furthermore, account should be taken of the possibility that the market for turtle eggs for incubation in hatcheries could also result in the harvest of eggs that would otherwise hatch in the wild. Economic and ecological analysis can be combined to identify the possible consequences for sea turtle conservation of turtle hatcheries reliant on economic support from tourists. This is the main objective of the paper. Before presenting the economic-ecological analysis, some background is presented about the nature of sea turtle hatchery-based tourism in developing countries.

Background about the nature of sea turtle hatchery-based tourism in developing countries, especially Sri Lanka

Hatchery-based *ex situ* conservation practices are widespread in sea turtle conservation (cf. Shaker 2003; Chan 2001; NRC 1990). The main objective of an open-cycle hatchery[2] is to secure eggs laid on unprotected beaches by removing them and incubating them under natural conditions and releasing the hatchlings back into the ocean. This way eggs are protected from threats including egg collectors, predators, damage by beach users and the possibility of eggs being washed to the sea during rough and high seas. This action can ensure higher hatchling rates and affords protection to hatchlings until they are released to the ocean. This practice normally involves purchasing eggs from local villagers.

Many such hatcheries have been in existence for several decades (cf. Shanker 2003; Pritchard 1980; Wickramasinghe 1982; Fernando 1977). The main objective of these hatcheries has usually been to prevent eggs from being used for human consumption. However, they now have become an important tourist attraction in some countries, such as Sri Lanka (cf. Mackensen 2002). Hatcheries catering for tourists hold hatchlings in small artificial seawater ponds for a few days after they are hatched before releasing them to the ocean nearby. The hatchery program involves ranching to some extent and its 'justification' is that it provides baby turtles with a headstart, claimed to result in a larger number of marine turtles surviving in the wild than would occur without this intervention. Such hatcheries also often hold a few sub adult or adult turtles to provide some extra interest to tourists[3].

Showing sea turtles to tourists, especially hatchlings, is a very lucrative business compared to using eggs for human consumption (cf. Amarasooriya 1999). Income is generated in many ways by these hatcheries. First the tourists are charged to view sea turtle hatchlings in tanks and they are also encouraged to view hatchlings emerging and to release them for a payment. Furthermore, there is the incidental sale of souvenirs to tourists. Tourists also donate money at these hatcheries for sea turtle conservation. In other words, there is 'value adding' to eggs that otherwise would have been consumed directly.

All sea turtle hatcheries in Sri Lanka are open to visitors to view hatchlings as well as a few adults. Visitors can see sandy areas where the turtle eggs are being incubated, can

view and even hold hatchlings held in seawater tanks and a few adult turtles are usually on display. Guides may provide some interpretation for visitors. This type of manipulation of nature is promoted by those who run hatcheries as a form of 'ecotourism' and they claim they are making a positive contribution to the conservation of marine turtles (Gampell 1999). The main justification is often claimed to be that the money generated from tourism (e.g. entrance fees and donations) is re-invested in purchasing eggs from collectors that otherwise would be consumed. Initially turtle hatcheries were started in Sri Lanka with the prime objective of sea turtle conservation only in mind (cf. Wickramasinghe 1982; Fernando 1977). However, according to Amarasooriya (2001) only two hatcheries in operation today have conservation in mind as their main objective and the rest are maintained primarily for commercial gains.

It is, however, often difficult to determine the main objective of an enterprise, especially a turtle hatchery. Furthermore, the desire for commercial gain need not be inconsistent with the promotion of nature conservation. It all depends, as is clear from the analysis given in this paper.

The number of sea turtle hatcheries in Sri Lanka has fluctuated in recent years. Richardson (1994) recorded 16 hatcheries in the southwestern and the southeastern coast, but this number declined to 7 in 1996 (Amarasooriya and Dayaratne 1997). By the end of 2000 there were 9 such hatcheries (Amarasooriya 2001). The general tendency in recent years has been for the average size of those hatcheries to increase as measured by their annual average utilization of eggs. On average, each hatchery buried approximately

19,311 eggs in 1981/82[4], 14,286 eggs in 1996 and 33,333 eggs in 2000 as can be seen by dividing egg numbers given in Figure 1 by the number of establishments.

As can be seen from Figure 1, the number of eggs used in hatcheries has shown a phenomenal increase. In 1981/82[4], only 48,934 eggs were used in three hatcheries (Wickramasinghe 1982). At that time, hatcheries had few tourists and were mainly used for conservation. However, the number of eggs purchased by hatcheries increased as sea turtle hatcheries became major tourist attractions.

Figure 1

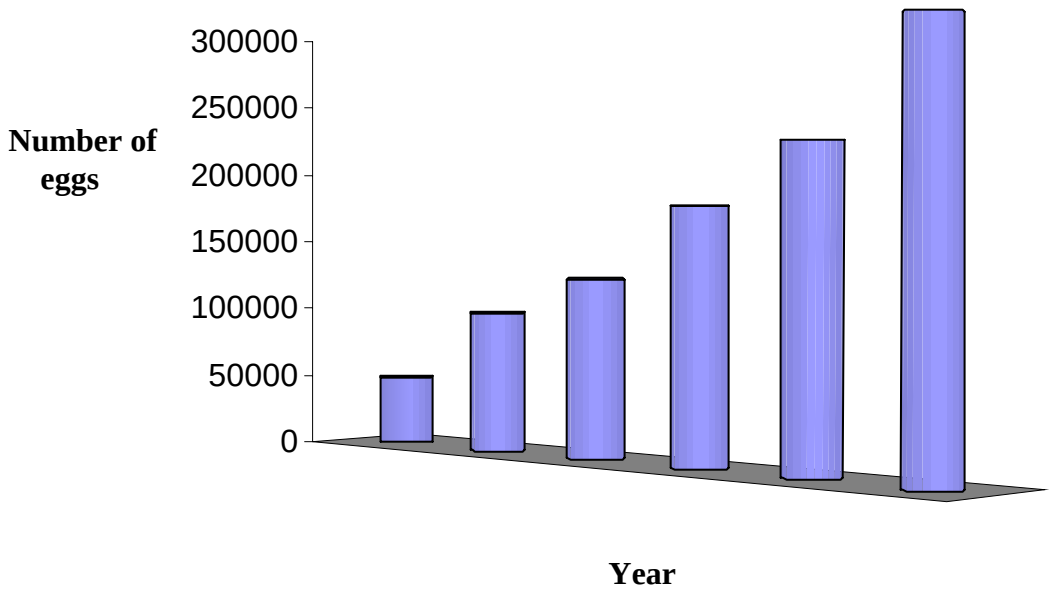

Figure 1: Number of sea turtle eggs used in hatcheries

Sources. 1981/1982[4] - Wicramasinghe (1982)
1996-2000 - Amarasooriya (2002)

The importance of tourism for some hatcheries (as discussed in notes) is underlined by the fact that they only operate during the main tourist season (Hewavisenthi 1993). This results in the number of collected eggs used in hatcheries fluctuating according to the tourist season. In Sri Lanka, turtles nest throughout the year with the peak season occurring for the Galle district (covers sea turtle nesting sites in the southwestern coast) in the period November to May, and for the Hambantota district (covers sea turtle nesting sites in the southeastern coast) in the period May to August (Amarasooriya 1999). See Figure 2 for those locations.

Figure 2

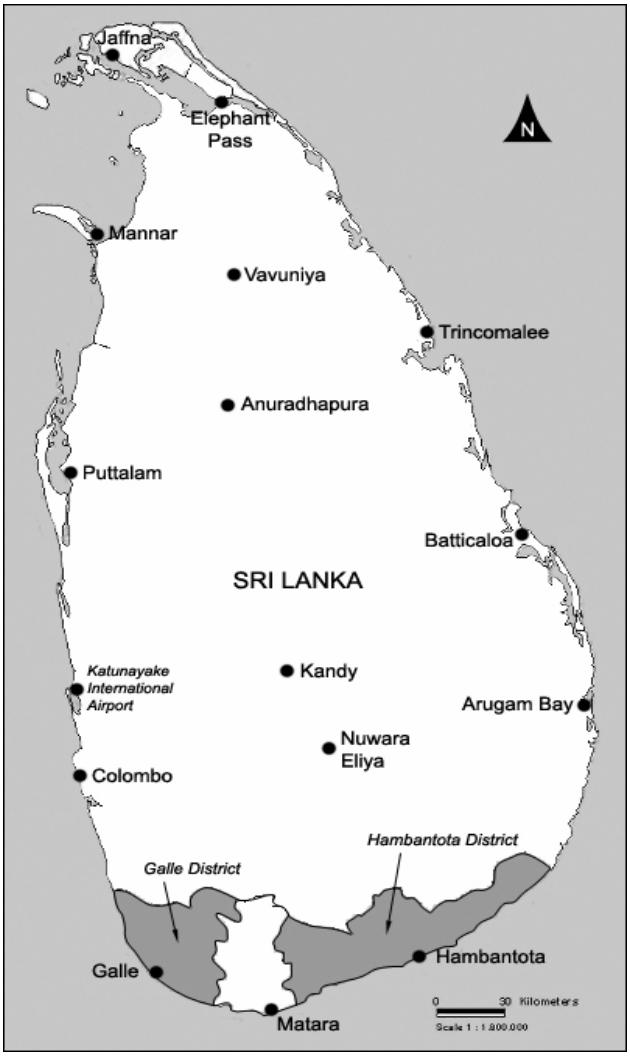

Figure 2 Map of Sri Lanka showing the Galle and Hambantota districts, the only locations for turtle hatcheries in Sri Lanka

Data collected by Amarasooriya (2001) show that the largest collection of reburied eggs by the hatcheries coincides with the peak tourist season, which starts in November/December and continue to April/May and that use of eggs by hatcheries declines during the low tourist season. Most eggs utilized by hatcheries are acquired by hatcheries on the southwestern coast of Sri Lanka. These account for 98 percent of eggs utilized by hatcheries in Sri Lanka and the remaining two percent are utilized in the southeastern of the island (Amarasooriya 2001). See Figure 2 for the two main districts where the majority of eggs are used.

Two factors probably help to explain the difference. Much more tourism is concentrated on the southwest coast of Sri Lanka than the southeastern coast, due partly to its close proximity to Colombo. This makes for relatively higher demand for tourism-based hatcheries in the south. Secondly, the peak turtle-nesting season in the Galle district virtually coincides with the peak tourist season. Both extend approximately from November to May. However, in the Hambantota district, there is virtually no overlap of the peak tourism period with the peak nesting season for turtles (May to August inclusive in this district) and the period of peak nesting of turtles is shorter in the Hambantota district than in the Galle district. Seasonal tourism demand combined with favourable supplies of turtle eggs provides an advantage for the Galle district compared to Hambantota district.

Amarasooriya (2001) estimates that the annual income of hatcheries in Sri Lanka is more than Rs 27 million a year or approximately US $340,562. The number of egg collectors

is estimated to be 35 and the hatcheries provide direct employment to approximately 175 persons who support over 650 dependents (Amarasooriya 2001).

In Sri Lanka, not all collected eggs are used in hatcheries, unlike in some places in Malaysia (Chan 1999). Amarasooriya (2001) estimates that around 33% of the eggs collected in Sri Lanka are used in hatcheries. This number is increasing as can be seen from Figure 1 above. This means that about two-thirds of sea turtle eggs collected in Sri Lanka are currently consumed. The trend is for this proportion to decrease.

The following arguments are proposed by those emphasising the positive contribution of those hatcheries to the survival of populations of sea turtles.

1. Turtle eggs that may have otherwise been collected and eaten by humans are supplied to the hatchery because it pays for those eggs. These are hatched and contribute to the maintenance of turtle populations.
2. Under hatchery conditions, eggs are afforded greater protection from land natural predators and so a larger number of eggs remain to produce hatchlings.
3. Furthermore, hatchlings obtain greater protection under hatchery conditions from natural predators than occurs in the wild and can be released to the ocean at a propitious time, when few predators, such as birds, are likely to kill them.
4. Nursery hatchlings can also be released at places where they will not be attracted inland by lights and consequently perish.

5. A further advantage could be that villagers who collect turtle eggs for the hatchery trade may dissuade other collectors from collecting these eggs for human consumption. Trade from human consumption often persists in developing countries despite being illegal.

While those consequences are possible, the final results depend on how well the hatcheries are managed. Some managerial criticisms of hatcheries include: (1) that hatcheries could produce 100% female hatchlings (cf. Shanker and Pilcher 2003); (2) hatchery raised hatchlings could carry disease (cf. Higgins 2003); (3) hatchlings could become too weak if they are raised in tanks for long periods of time without appropriate care (Hewavisenthi and Kotagama 1990); (4) hatchlings held in crowded tanks are more likely to cause injury to each other (Hewavisenthi 1993); (5) marine predators are likely to become more active when hatchlings are released from a few beaches, especially at set times (Pritchard 1980); (6) hatchlings raised in tanks, even for a few days could loose their 'imprinting mechanism' which is thought to be necessary to enable adult females to return to the same beach to nest (Pritchard 1980); (7) releasing hatchlings only from a few beaches, could in the long term, affect the nesting distribution and species' composition; (8) handling of eggs and their transportation, especially for long distances could increase the mortality rates of hatchlings; and (9) tourists' handling of hatchlings and the practice of digging up transplanted nests to show visitors and release of hatchling by tourists during the day could affect hatchlings (Hewavisenthi 1993). However, all these problems can be addressed in principle and guidelines for the appropriate maintenance of hatcheries have been formulated (cf. Higgins 2003; Mortimer 1999; IUCN/SSC Marine Turtle Specialist Group 1999).

Analysis: economic considerations

The application of simple economic supply and demand analysis to this issue can be illustrated by Figure 3. In this figure, X_3 is assumed to be the total number of sea turtle eggs of all species laid on relevant beaches in a period of time, and the line SS represents the supply of harvested turtle eggs at alternative prices for these. Suppose that the demand for harvested turtle eggs for consumption exists as shown by the line marked D_c D_c. Then in the absence of demand from hatcheries for eggs, the market equilibrium for harvested turtle eggs is E_1. Turtle eggs sell for P_1 each and X_1 eggs are harvested in the period. X_3 -X_1 eggs remain unharvested.

Figure 3

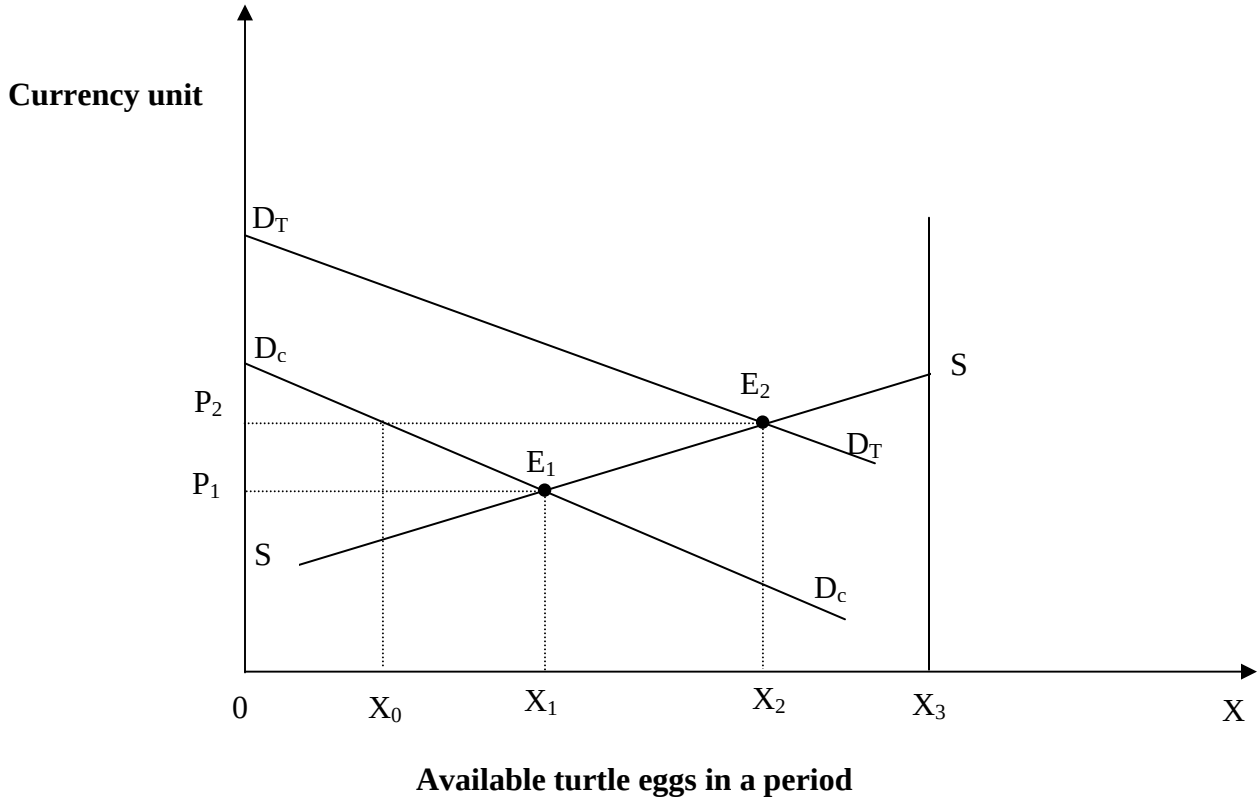

Figure 3 Demand and supply relationships for harvested turtle eggs. Market equilibrium shown before and after the presence of hatcheries

Suppose now that an additional demand for turtle eggs arises from hatcheries, due to tourism, while all other factors remain the same. In Figure 3, the consequence may be that the total demand for turtle eggs shifts rightwards as indicated by the demand curve marked D_T D_T. The difference between this line and the line marked D_c D_c represents the extra demand generated by hatcheries for eggs. A new market equilibrium is now established at E_2. Consequently, the equilibrium price of eggs rises to P_2 and the harvest of eggs rises to X_2. Therefore, there are fewer eggs, X_3-X_2, now left to hatch in the wild.

The extra supply of eggs for the hatcheries comes from two sources: (a) eggs that would otherwise be consumed, ($X_1 – X_0$) in the case shown in Figure 3 and (b) from increased harvesting of eggs from the wild (X_2 - X_1) in the case illustrated in Figure 3. If the demand curve for turtle eggs for consumption is steeper than that of the supply curve, the largest share of the increased nursery supply will come from increased harvesting of eggs. If the reverse relationship holds, the opposite conclusion follows.

As can be seen from Figure 3, if the demand for harvested eggs for hatcheries becomes very high, then there is a tendency for virtually all eggs laid in the wild, possibly including those on remote beaches and national parks, to be collected. The consumption of eggs, may also fall to low levels. The prospects for survival of populations of turtles will then increasingly come to depend almost completely on turtle hatcheries.

There are two possible end-point cases. One involves situations in which no collection of eggs for human consumption occurs. In this case, open-cycle turtle hatcheries can only

be justified from a conservation viewpoint if they result in greater additions to populations of adult turtles than would occur in the wild. In the second case, all, or virtually all, eggs that are laid in the wild by sea turtles may be collected for human consumption. Where X_3 is the quantity of eggs laid, the situation illustrated in Figure 4 may emerge. There the supply curve of harvested eggs is SSA. The demand for harvested eggs for human consumption is D_cD_c and is so high that market equilibrium is initially at E_1 with all eggs collected and consumed. Suppose now that hatcheries add to demand by the difference between D_TD_T and D_c D_c. A new market equilibrium is established at E_2. Consequently, hatcheries save $X_3 - X_0$ of eggs from human consumption. Therefore, if they have some success in ensuring that some of these eggs will result in turtle adults, they help stem declining turtle populations. But this does not mean that they will necessarily be able to stem the decline in such populations.

Figure 4

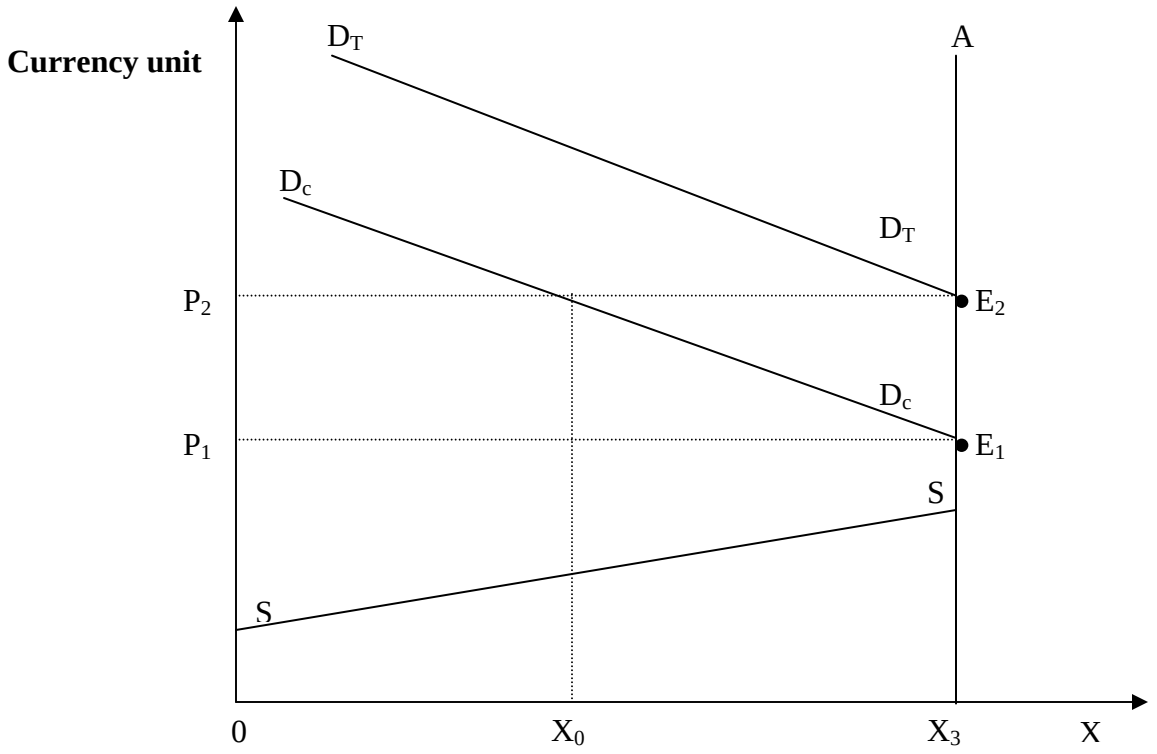

Figure 4 A case in which all turtle eggs are harvested and consumed prior to hatcheries entering the market. Market equilibrium shown before and after the presence of hatcheries

The heavy reliance on hatcheries in these instances may result in a positive outcome given the fact that most eggs would otherwise be consumed by humans. In some developing countries (e.g. India, Indonesia and Sri Lanka), because the collection of turtle eggs is illegal, the trade has gone underground. However, consumption of eggs still takes place as before. Legislation to ban egg collection has had little impact. In such

instances, the situation in the absence of hatcheries could be much worse for sea turtles because all eggs are consumed. Hatcheries, at least can resort to some form of *ex situ* conservation. These circumstances should not be used as an excuse for lax management resulting in few collected eggs for hatcheries producing adult turtles. However, for hatcheries to make a satisfactory contribution to sea turtle conservation, the management and outcomes of these hatcheries need to be of an acceptable standard.

In this analysis the eggs of all species of sea turtles are treated as homogenous. However, there could be differences in prices of eggs depending on the rarity of species, taste preferences among consumers and preferences of hatchery operators. For instance, the leatherback, *Dermochelys coriacea*, hatchlings are more difficult to raise in tanks even for a few days than some other species (cf. Higgins 2003). Hence, there is the possibility of egg selection by consumers as well as hatchery operators, but in the paper, we assume that these factors do not affect the general analysis.

Critical ecological/economic condition to be satisfied for hatcheries to help conserve turtle populations

A simple relationship can be used to determine whether sea turtle hatcheries assist in the survival of turtle populations or not. Let a_1, represent the proportion of turtle eggs that eventuate under 'natural' conditions in hatchlings entering the ocean and let a_2 represent this for turtle eggs used in hatcheries. Furthermore, let R represent the amount of eggs saved from human consumption by hatcheries (it corresponds to $X_1 - X_0$ in Figure 3) and let W represent the amount of extra eggs collected from the wild to satisfy hatchery needs (it corresponds to $X_2 - X_1$ in Figure 3).

Let S represent the difference arising from the presence of hatcheries in the number of turtle hatchlings entering the ocean, that is the difference compared to one in which no hatcheries exist[5]. Then:

$$S = Ra_2 + W(a_2 - a_1)$$

The term Ra_2 indicates the number of hatchlings surviving to enter the ocean from eggs buried by hatcheries. These eggs are no longer consumed by humans. The term $W(a_2 - a_1)$ specifies the difference in the number of hatchlings entering the ocean from eggs collected by hatcheries that otherwise would be left to their fate in the wild. In principle, R and W can be determined for the model in the last section, and a_1 and a_2 are ecological parameters.

If $S = Ra_2 + W(a_2 - a_1) > 0$, hatchery operations increase the number of turtles surviving to enter the ocean. On the other hand, this relationship can be negative if a_1 is larger than a_2. Hatcheries can then have a negative effect on the number of turtles surviving to reach the stage of ocean entry[6]. If hatcheries are poorly managed, S could be conceivably negative, especially if the impact of hatcheries on the collection of extra turtle eggs for human consumption is low. There is also the possibility that $S = 0$, in which case, the presences of hatcheries has no impact on the survival of turtles to the ocean entry stage.

From the above discussion, it can be seen that the survival indicator for sea turtles headstarted through hatcheries is positive, zero or negative.

$$S \gtreqless 0,$$

according to whether

$$Ra_2 \gtreqless - W (a_2 - a_1)$$

Therefore, if $Ra_2 > 0$, that is, some eggs go to hatcheries that would otherwise be consumed by humans and some of those result in hatchlings that survive, then S can exceed zero, even if $a_2 < a_1$. But other things equal, it is less likely to do so the smaller is R (number of eggs saved from human consumption), the lower is a_2 (the survival rate of hatchery 'headstarted' turtles), and if $a_2 < a_1$, the greater is the number of eggs withdrawn by nurseries from the wild that would otherwise pass through a natural cycle.

Observe that if R = 0, that is, if hatcheries have no impact on human consumption of turtle eggs, $S \gtreqless 0$ according to whether $a_2 \gtreqless a_1$; the effectiveness of hatcheries in conserving sea turtle populations depends primarily on whether the survival rate of nursery started turtles exceeds than those in the wild. R may equal zero because the demand for turtle eggs for human consumption is perfectly inelastic or because there is no harvest of turtle eggs for human consumption. The latter could happen, if for instance, legislation banning the collection of turtle eggs for human consumption, is completely effective. It may also happen because the demand of hatcheries for turtle eggs, leads to a hike in the price which forces consumers of turtle eggs out of the market. In Figure 3, this would involve a market price higher than any price along the line D_cD_c, but this is unlikely. Note that as R becomes smaller, the effectiveness of hatcheries in conserving

turtle populations becomes increasingly dependent on hatcheries achieving higher survival rates for turtles than would occur from natural processes.

In some developing countries, such as Sri Lanka, as discussed in Section 2, the demand for turtle eggs in hatcheries is mainly a demand derived from tourist visits to such hatcheries. The demand derives from the willingness of tourists to pay fees to enter such hatcheries, to release hatchlings to the ocean for a payment, to donate money to support the conservation efforts of hatcheries, and to purchase souvenirs and other items while visiting hatcheries. Increases in tourist demand, displayed by increased outlays for such items, results in greater demand for turtle eggs for hatcheries.

Two effects are likely to occur with rising tourist demand involving turtle hatcheries: (1) the operation of hatcheries becomes more profitable and this is likely to encourage additional enterprises to enter the industry, and (2) the demand of existing hatcheries for eggs is at least maintained or may be expanded. The latter is quite evident in Sri Lanka as noted above. Consequently, less eggs are available for human consumption and above all fewer and fewer turtle eggs are left in the wild. In such situations most turtle eggs have to rely on hatcheries for incubation and turtle hatchlings also become hatchery dependent. In those circumstances, the standard of management of the hatcheries becomes crucial for the survival of sea turtles. Whether or not private individuals who run these hatcheries in developing countries are in a position to maintain appropriate management standards. In principle, at least, greater public regulation of standards is desirable.

Discussions and concluding comments

Several species of sea turtles are endangered and various policies including 'headstarting' intervention by hatcheries have been adopted with a view to halting or reversing their decline in populations. In some developing countries, most hatcheries have arisen from private initiatives to take advantage of the tourist trade. They are often motivated by a mixture of commercial and some conservation aims.

The effectiveness of such hatcheries in halting or reversing declines in populations of wild sea turtles is unclear. Depending on the values of the survival variables identified in this paper, the impact of turtle hatcheries on the numbers of turtle hatchlings entering the ocean may be positive or negative. The actual values need to be identified empirically, and may vary between hatcheries and locations. However, given the increasing prevalence of sea turtle hatcheries in many developing countries, urgent consideration needs to be given to estimating these parameters in practical situations.

As 'ecotourism' based on turtle hatcheries expands, the need to monitor the impacts of the hatcheries on adult populations of sea turtles grows because tourist expansion can be expected to increase the demand of hatcheries for sea turtle eggs. With expanding demand, as shown by the economic model used in the paper, the proportion of remaining turtle eggs left to hatch in the wild may dwindle to insignificant proportions of the total clutches laid, if in fact not all turtle eggs are already being collected for human consumption. In all these situations, the survival of the populations of sea turtles becomes almost completely dependent on the ability with which hatcheries are managed.

This situation is already apparent in some developing countries such as Sri Lanka. Unless appropriate management strategies are maintained by turtle hatcheries, they can do more harm than good for conservation of sea turtles[7].

Apart from this, it is uncertain how effective 'headstarting' programs of this nature are in increasing adult populations of targeted species. In addition, many conservationists have negative feelings about most sea turtles starting their lives in hatcheries rather than in the wild (cf. Shanker and Pilcher 2003). Moreover, depending on hatchery conditions, sex-ratios of turtles may be unfavourably altered by hatcheries (cf. Tiwol and Cabanban 2000) and hatcheries could in the long-term favour the survival of strains less fit to survive in the wild.

It is also true that tourism-based hatcheries that mainly have profit maximization as their objective can be inclined to sacrifice conservation objectives to some extent. For instance, hatchlings emerging from buried nests are not immediately released to the sea, but are kept in tanks, often for several days to show tourists and also to allow willing tourists to release hatchlings in return for a payment. Delaying the release of hatchlings to the ocean saves money for hatcheries because they do not have to purchase as many eggs as otherwise to keep hatchlings on display for tourists. This can result in hatchlings being weak when released to the ocean and increase the likelihood of their injuring one another thereby seriously reducing survival rates. Furthermore, holding ponds are often extremely small (to save money and space) and quite crowded so adding to injuries.

Nevertheless, the above should not be taken to imply that hatcheries are unable to make a positive contribution to the conservation of sea turtles. In fact they are recommended as a last resort where *in situ* conservation is not possible or impractical (cf. IUCN/SSC Marine Turtle Specialist Group 1999; IUCN 1995). The paper is intended to counter the perception that turtle hatcheries inevitably make a positive contribution to the conservation of sea turtles and that their consequences for populations in the wild are bound to be positive. Furthermore, even when hatcheries make a positive contribution to the conservation of sea turtles, it should not be forgotten that there is often scope for improving their performance in this regard.

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Notes

1. In fact, Amarasooriya (2001) argues that this is often an indication that the prime motive of such hatcheries is profit rather than conservation. This is because their profits during the main tourist season would be sufficient to finance their hatchery activities in the off season. However, since the tourist revenue in the off season is less than their operating expenses (variable costs) they may generate more profit by ceasing their conservation efforts and closing down their hatcheries.
2. There are few closed cycle turtle hatcheries. However, one was established in the Cayman Islands for green turtles.
3. These are sometimes claimed to injure turtles.
4. Data is available only from early December 1981 to early, May 1982.
5. Note that it should not be forgotten that a_1 may be subject to human manipulation or influence. The higher is a_1, other things equal, the less the scope for hatcheries to make a positive contribution to conservation of turtle populations.
6. S is implicitly used as an indicator of the influence on the sea turtle populations compared to a situation where they do not exist. However, if hatchlings entering the ocean from hatcheries are weaker than those from the wild, and, therefore, have less chance of surviving to become adults, the indicator should be adjusted to allow for this. To do this is straightforward in principle. Furthermore, note that the possibility of a change in sex ratios has been ignored.
7. In Sri Lanka, hatcheries are strictly speaking involved in illegal operations in their turtle-raising practices. However, since they have convinced the public and others that they make a positive contribution to the conservation of sea turtles their presence

is ‘unofficially’ sanctioned and their collection of eggs is seen as ‘justified’. There are consequently few, if any, prosecutions for illegally collecting turtle eggs, although it is prohibited by law.

References

Amarasooriya, K. (2001), *The Role of Sea Turtle Hatcheries in the Conservation of Sea Turtle Fauna of Sri Lanka*, Paper Presented at the 21st World Sea Turtle Symposium, Philadelphia, USA.

Amarasooriya, K. (1999), *A Classification of the Sea Turtle Nesting Beaches of Southern Sri Lanka*, Paper Presented at the 22nd ASEAN Symposium and Workshop on Biology and Conservation of Sea Turtles, Kota Kinabalu, Sabha, Malaysia.

Amarasooriya, K and P. Dayaratne (1997), *A Survey on the Existing Turtle Hatcheries and Mapping of the Existing Beaches of Turtles along the Northeast, West, Southwest, South and Southeastern coasts of Sri Lanka*. A report forwarded to the National Science Foundation of Sri Lanka, Colombo, Sri Lanka.

Chantrapornsyl, S. (2002), *Marine Turtle Conservation Programmes in Thailand*. In: Procs. Workshop on Marine Turtle Conservation, Sihanoukville, Department of Fisheries, Cambodia.

Chan, E. H. (2001), *Status of Marine Turtle Conservation and Research in Southeast Asia.* In Procs. Viet Nam’s first National Workshop on Marine Turtle Conservation, IUCN-Vietnam and Ministry of Fisheries.

Fernando, R. (1977), ‘Turtle Hatcheries in Sri Lanka’, *Marine Turtle Newsletter* **3**: 8.

Hewavisenthi, S. (1993), ‘Turtle Hatcheries in Sri Lanka: Boon or Bane?’, *Marine Turtle Newsletter* **60**: 19-21.

Hewavisenthi, S. and S. W. Kotagama (1990), 'The Effect of Retaining Turtle Hatchlings in Tanks before their Release', *Proceedings of the Sri Lanka Association for the Advancement of Science* **46**: 92 (abstract).

Gampell, J. (1999), ' To Save the Turtles' *Reader's Digest*, May Issue (Asian Version).

Higgins, B. M. (2003), 'Sea Turtle Husbandry', Chapter 16, in P. L. Lutz, J. A. Musick and J. Wyneken, eds., *The Biology of the Sea Turtles*, CRC Press, Washington, D.C.

Higginson, J. and F. Vasquez, (1989), 'Hatchery Design and the Production of Female Hatchlings', *Marine Turtle Newsletter* **44**: 7-12.

International Union for the Conservation of Nature (1995), *A Global Strategy for the Conservation of Turtles*, Prepared by IUCN/SSC Marine Turtle Specialist Group, Cambridge, UK.

International Union for the Conservation of Nature/SSC Marine Turtle Specialist Group, (1999), *A Global Strategy for the Conservation of Marine Turtles*, http://www.tortugas.unam.mx/mtsg/english/mtsg_publications-english.htm.

Mackensen, A. (2002), *Contributions to Sea Turtle Conservation in Sri Lanka: Growth Rates, Socio Economic Data and Nesting Patterns*, MSc Thesis in International Studies in Aquatic Tropical Ecology, Presented to the University of Bremen, Faculty for Biology and Chemistry, Germany.

Marcovaldi, M. A. G. and Thome, J. C. A. (1999), 'Reducing Threats to Turtles' in K. K. Eckert, F. A. Bjorndal, F. Abreu-Grobois, and M. Donnelly, eds., *Research and Management Techniques for the Conservation of Sea Turtles*, IUCN/SSC Marine Turtle Specialist Group, Publication No.4, 165-168.

Mortimer, J. A (1999), 'Reducing Threats to Eggs and Hatchlings: Hatcheries' in K. K. Eckert, F. A. Bjorndal, F. Abreu-Grobois, and M. Donnelly, eds., *Research and Management Techniques for the Conservation of Sea Turtles*, IUCN/SSC Marine Turtle Specialist Group, Publication No.4, pp. 175-178.

National Research Council (1990), *Decline of the Sea Turtle*, National Academy Press, Washington, DC.

Prichard, P. C. H. (1980), 'The Conservation of Sea Turtles: Practices and Problems', *American Zoologist* **20**: 609-617.

Shanker, K. (2003), 'Thirty Years of Sea Turtle Conservation on the Madras Coast: A Review', *Kachhapa* **8**:16-19.

Shanker, K. (1994), 'Conservation of Sea Turtles on the Madras Coast', *Marine Turtle Newsletter* **64**: 3-6.

Shanker, K and N. Pilcher (2003), 'Marine Turtle Conservation in South and Southeast Asia: Hopeless Cause or Cause for Hope?', *Marine Turtle Newsletter* **100**: 43-51.

Pilcher, N. (1999), 'Turtles Turned Turtle', *Asian Geographic* **2**: 56-69.

Pilcher, N and G. Ismail (1999). *Sea Turtles of the Indo-Pacific – Research, Management and Conservation*, ASEAN Academic Press London.

Richardson, P. (1994), *Marine Turtles of Sri Lanka*. ACCD-GTZ Environmental Education and Public Awareness Publications, Coast Conservation Department.

Tiwol, C. W. and A. S. Cabanban (2000), 'All Female Hatchlings from the Open-beach Hatchery at Gulisaan Island, Turtle Islands Park, Sabah', in eds., N. J. Pilcher and M. G. Ismail, *Sea Turtles of the Indo-Pacific: Research, Management and Conservation*, ASEAN Academic Press London, Audio Version.

Upm, U. M. S. and J. Perhilitan (1996), *Development and Management Plan: Turtle Islands Park*, Sabah Parks, Sabah, Malaysia.

Wickramsinghe, S. (1982), 'Turtle Hatcheries in Sri Lanka', *Marine Turtle Newsletter* **22**: 3-4.

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